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XVII. *On different Properties of Solar Radiation producing or preventing a deposit of Mercury on Silver Plates coated with Iodine, or its compounds with Bromine or Chlorine, modified by Coloured Glass Media and the Vapours of the Atmosphere.*
By A. CLAUDET, Esq. Communicated by Sir DAVID BREWSTER, F.R.S., &c. &c.

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FROM the commencement of photography it has been known that the red, orange, and yellow rays exert but a very feeble photogenic influence on the Daguerreotype plate. The experiments of several philosophers, especially those of Sir J. HERSCHEL on photogenic papers, published in February 1840, prove that this action is more particularly confined to the most refrangible part of the prismatic spectrum, commencing from the space found covered by the blue rays and extending to the extremity of the violet, and sometimes even beyond it.

In 1839, Sir J. HERSCHEL observed that the red rays exercised on several photogenic papers an antagonistic action to the photogenic rays, modifying their effect. Contrary to this, in 1841, M. ED. BECQUEREL presented to the Paris Academy of Sciences a memoir, in which he announced that the red, orange and yellow rays were endowed with the property of continuing the action commenced by the photogenic rays; these latter he called *exciting rays*; to the first he gave the name of *continuing rays*.

M. ED. BECQUEREL made his experiments on photogenic papers, and added that he had observed the same effects on the iodized silver plate.

Dr. DRAPER of New York published in the Philosophical Magazine for November 1842, some remarks on a class of rays which he supposed to exist in the light of the brilliant sun of Virginia, and which had the property, when separated, of entirely suspending the action of the diffused light from the sky; these antagonistic rays extended from the blue to the extremity of the red, and appeared to be almost as active in preventing the decomposition of the iodide of silver as the blue rays were in producing it.

In January 1845 a memoir was read by me at the Society of Arts, London, in a part of which I recommended opticians to construct object-glasses in which they should particularly correct the chromatic aberration of the long photogenic space of the solar spectrum, even at the cost of the achromatism of the less refrangible rays. This, however, had been already indicated, without my being aware of it at the time, by Sir J. HERSCHEL; but I added that the greater separation of the visual and photogenic focus which might result from such a combination, according to the quality

of the glass employed, would be an advantage, by dispersing, at the focus or on the plate, beyond the photogenic lines, the red, orange or yellow rays; for the reason, that if they were brought to the same point they would tend to neutralize and destroy the effect of the photogenic rays.

In October 1846, M. LEREBOURS announced to the Paris Academy of Sciences that the red rays prevented the action of the photogenic rays; this announcement induced Messrs. FOUCAULT and FIZEAU to publish immediately similar results, which they had previously consigned to the Academy in a sealed memoir, bearing date May 1846.

These communications of Messrs. LEREBOURS, FOUCAULT and FIZEAU, led Dr. DRAPER to write a letter, published in the Philosophical Magazine of February last, repeating his observations on the spectrum of Virginia, adding several other analogous facts confirming the theory of a protecting and even destroying action exercised by the least refrangible rays. Dr. DRAPER, in the same letter, said that the rays which protect the plate from ordinary photogenic action are themselves capable, when isolated, of producing a peculiar photogenic effect.

Soon after the publication of M. ED. BECQUEREL's memoir, M. GAUDIN made some analogous researches on the Daguerreotype plate; and he succeeded in developing an image as perfect as that produced by mercury, by submitting the plate, when taken from the camera obscura, to the action of light alone under a yellow glass, and without any subsequent exposure to mercury.

This curious discovery gave some hope that, from the supposed continuing action of the red and yellow glasses, by submitting the plate alternately, or simultaneously, to the action of the mercury and of these glasses, an accelerated development of the image would result; but all the researches made to arrive at this point have been fruitless; and, until the present time, the labours of Messrs. BECQUEREL and GAUDIN have received no satisfactory explanation or useful application.

My own experiments, which are the object of this memoir, seem to prove that M. ED. BECQUEREL was mistaken as regards the Daguerreotype plate, in so far as he attributed to the red, orange and yellow glasses a continuing action of the effect of the photogenic rays.

In the Daguerreotype, when we speak of the *photogenic effect*, we cannot understand any other than that which gives to the surface an affinity for mercurial vapour.

In the case of photogenic papers, it is true that the red, orange, and yellow rays render the parts previously affected by the photogenic rays black or of a darker colour. It is the same with the Daguerreotype plate, which after it has been feebly impressed, darkens rapidly to a violet colour under the radiation of a red or yellow glass. This is the only continuing effect I have observed, and this effect is not *continuing* in a Daguerreotype sense, it has no relation to the property of attracting the mercurial vapour; on the contrary, it will be seen from the experiments which I am about to describe, that the radiations of red, orange and yellow glasses entirely destroy this property. There exists then a certain analogy between the action of the

red, orange and yellow glasses upon the photogenic papers and the Daguerreotype plate; and this continuing action is probably due to the distinct photogenic action possessed by these rays, as I am able to prove by facts of a very positive nature.

These two photogenic actions result from two different principles, nevertheless producing similar effects, as to the colour obtained, on the iodide, bromide or chloride of silver, whether it be found isolated, as is the case on the photogenic paper, or it be found in the presence of metallic silver, as happens upon the Daguerreotype plate; but they produce quite an opposite effect upon the silver plate, whatever may be the colour previously given to the surface by these two radiations, endowing it with a property, the one of attracting, the other of repelling the mercurial vapours. We must take care not to confound these two results; we can conceive two different actions giving the same colour to the iodide of silver, and we can also conceive that these two actions may be endowed with contrary properties as regards the fixation of mercurial vapour.

The facts pointed out by M. GAUDIN are the results of an action which does not belong to the Daguerreotype, since they are manifested without the aid of mercury; for we must not lose sight of the fact, that the production of the Daguerreotype image is due only to the affinity for mercury of the parts previously affected by the photogenic rays. It does not then follow from the production of an image without mercury, by crystallization or some peculiar arrangement of the molecules, that the red, orange, and yellow rays exert a continuing action analogous to that which determines the fixation of mercurial vapour.

The experiments of Sir J. HERSCHEL, of Dr. DRAPER, of M. LEREBOURS, and of Messrs. FOUCAULT and FIZEAU, to prove the protective and destructive action of the red rays, were made with the prism.

These philosophers have thus operated with the isolated rays in all their natural purity, and after them it would have been useless to seek to confirm or to contradict experiments so ably conducted and so conclusive.

Sir J. HERSCHEL, in a memoir published in the Philosophical Magazine for February 1842, approves only of experiments made by means of the prism, as they are less subject to error from the foreign rays, which the coloured glasses never entirely exclude. This observation is perfectly just in theory, but in practice, in the particular case of the photogenic power of different rays and of their different actions, it will be found that these phenomena can be studied with greater facility by using coloured glasses, and that the feeble quantity of foreign rays which they admit, far from interfering with the deductions of the experimenter, serve only to confirm and to render them more conclusive. We shall presently see that these foreign rays are completely neutralized in this class of experiments, and it would have been unfortunate not to have added these tests to those of the solar spectrum, since by the aid of coloured glasses I have been enabled, not only to confirm certain properties of the pure spectrum, but also to discover some others which had escaped my predecessors.

Having examined with a prism the light transmitted through the glasses used in these experiments, I found that the red absorbs two-thirds of the prismatic spectrum, from the space covered by the green to the extremity of the violet, leaving the red, orange, and a little yellow, followed by a very slight trace of green. The orange glass gave more yellow, the green being more decided. The light yellow glass intercepted the half of the spectrum; the red was less intense than in the preceding; the yellow occupied two-thirds of its total length, and the green became very distinct; but as far as my sight allowed me to judge, I could not discover any portion of blue in either case: certainly in the spectrum of the red glass there was not the least trace of it.

I will now detail the series of observations I have made upon light transmitted through certain media—the vapours of the atmosphere, and red, orange, and yellow glasses. These experiments have brought forth some results which will I hope contribute to lay the foundation of a more complete theory of the photographic phenomena.

Having noticed, one densely foggy day, that the disc of the sun was of a deep red colour, I directed my apparatus towards it. After ten seconds of exposure I put the prepared plate in the mercury box, and I obtained a round image perfectly black. The sun had produced no photogenic effect. In another experiment I left the plate operating for twenty minutes. The sun had passed over a certain space of the plate, and there resulted an image seven or eight times the sun's diameter in length: it was black throughout, so that it was evident, wherever the red disc of the sun had passed, not only was there a want of photogenic action, but the red rays had destroyed the effect produced previous to the sun's passage. I repeated these experiments during several days successively, operating with a sun of different tints of red and yellow. These different tints produced nearly the same effect: wherever the sun had passed there existed a black band.

I then operated in a different manner: not content with the slow motion of the sun, I moved the camera obscura from right to left, and *vice versâ*, lowering it each time by means of a screw. In this manner the sun passed rapidly over five or six zones of the plate. Its passage was marked by long black bands of the diameter of the sun, whilst the intervals were white. It was then evident that the red and yellow rays, which alone were capable of piercing the fog, had destroyed the action produced by the little photogenic light which came from the zenith.

I then operated with coloured glasses. After exposing a plate covered with a piece of black lace to daylight, I covered one half, and submitted the other to the radiation of a red glass: the mercury developed an image of the lace on the part which had been acted on only by the white light; the other, which had afterwards received the action of the red rays, remained black. The red glass had destroyed the photogenic effect in the same manner as it had been done by the red light of the sun.

I made the same experiment with orange and yellow glasses, and obtained analogous results, but in different times.

Then, having exposed a plate to daylight, I subsequently covered it with a piece of black lace, and exposed it again under a red glass : this produced a negative image. The red had destroyed the effect of the white light in the intervals of the lace, the threads of which preventing the action of the red glass, produced a white image upon a black ground. In operating in this manner upon one-half of the plate, exposing the other half covered only by the same lace to the light of the day, I obtained by the first a negative, and by the second a positive image. The orange and yellow glasses give the same result, paying regard to the difference of time in their respective actions.

All these experiments prove what has been already observed by others before me, but in a different manner, that the red, orange and yellow rays destroy the effect of the photogenic light, whether these rays be produced by the prism or by the action of coloured media ; but, I believe, it has not been observed by any one before me, that after the destruction of the photogenic effect the plate is perfectly restored to its former sensitiveness to white light.

After exposing a plate to daylight, and then submitting it to the destructive action of red, orange or yellow rays, it will be found again sensitive to the same white light.

I have obtained plates which present an equal and uniform image, although the one-half had been exposed to light, and then restored by the red, orange or yellow glass, while the other half had received only the single and final radiation. We may then expose a plate to light, destroy this effect by the action of red or yellow glass, which renders it again sensitive ; then expose it again to light, destroy this second effect by the same coloured glass, and so on for many times, without changing the properties of the surface ; so that if we stop after any of the exposures to white light, the plate will receive mercury ; but if we stop after any of the exposures to red, orange or yellow light, we shall obtain no fixation of mercurial vapour.

Having exposed a plate to the two actions alternately, first, once upon one zone, twice upon another, and so on until the last zone had been exposed and destroyed six times, I covered the plate with a piece of black lace or an engraving, finally exposing the whole to white light ; the result was an equal deposit of mercury upon the whole surface of the plate. The impression of the lace or engraving seemed to be the result of a single exposition to light, as would have been the case with a normal plate ; therefore the action of the red, orange, or yellow glass upon a plate previously affected by light, produces the same effect as a fresh exposure to the vapours of iodine or bromine, when we wish to restore the plate to its first sensitiveness.

This restoring property of the coloured glasses may be of great use in the Daguerreotype manipulation. Instead of preparing the plates in the dark, it may be done with impunity in the open light. To give sensitiveness, we have only to place the plate for some minutes under a red glass before putting it in the camera obscura. The frame or box used to hold the plate, if furnished with a red glass at the bottom,

will serve for this restoration. I have obtained in this manner images equal in effect to those produced on plates prepared in the dark.

This possibility of preparing plates in open day offers a great advantage to those who wish to take views or pictures abroad, and who cannot conveniently obtain a dark room. Again, in the case of a plate which has been left too long in the camera obscura, or accidentally exposed to the light, instead of rejecting it, we can restore its sensitiveness by placing it under a red glass. There is still another useful application of this property: if after one or two minutes' exposure to the mercury we perceive the image is too rapidly developing, or presenting signs of solarization, which a practised eye discovers before it is too much advanced, we have only to stop this accumulation of mercury by exposing the plate for a few seconds to the red light, and again place it in the mercury box, to complete the modifications, which give the image all its tones and the most favourable tint. In truth, we may complete all the operations of the Daguerreotype in the open air, in the middle of a field if necessary. We can introduce the plate into the mercury box, in the same manner that we did in the camera obscura, by means of the same frame and red glass, which also serves to protect it when we take it from the mercury to rapidly view its development. I say rapidly, for if we expose it too long to the red light, the photogenic effect will be neutralized. We shall presently see that the time required to observe the state of the image is not sufficient to affect its affinity for mercury, if it be found requisite to replace it in the mercury box. The exposure under red glass necessary to destroy the effect produced by white light, must be a hundred times longer than has been the exposure to white light, that of the orange glass fifty times, and that of the yellow glass only ten times; thus a plate exposed to white light for a second will be restored to its former sensitiveness in ten seconds by the yellow glass, in fifty by the orange, and in a hundred by the red. As soon as the sensitiveness of the plate affected by white light is restored by the coloured glasses, it may be affected again by the photogenic light. It is not even necessary that the restoration should be complete; at each degree of restoration the plate is capable of receiving an accumulation of photogenic effect. If the red rays have not acted more than fifty times longer than the daylight, only half of the effect will be destroyed; if twenty-five times longer, one-fourth; and so on in proportion.

Besides the destructive action of the red, orange and yellow glasses, these same radiations are endowed with a photogenic power, that is to say, they have, like the blue and violet rays, the power of causing the fixation of mercurial vapour. Therefore these radiations are endowed with two contrary actions; the one destructive of the effect of the photogenic light, and the other analogous to the effect of this light.

If the red, orange and yellow radiations of the prism had not also the power of operating photogenically, it might be supposed that this action of the coloured glasses was due to some of the most refrangible rays transmitted by these coloured media. But this cannot be; for if the photogenic action of the red, orange and yel-

low rays were the same as that of the more refrangible rays, it could never develop itself under the destructive action which the same glasses carry with them.

But there is yet more; each ray of the spectrum has its own photogenic action, and they are in this respect independent of each other, and of a different kind; so that the one cannot continue the effect commenced by the other, whether it be for the production or for the destruction of the photogenic effect. I would again observe, whenever I speak of a photogenic effect, I mean that which gives to the Daguerreotype plate the property of attracting the vapours of mercury.

If we expose a plate covered by an engraving to the red light 5000 times longer than is required to produce an effect by white light, we obtain by the fixation of mercury a feeble image, the lights of which are of a grey tone. I could never go beyond this feeble image, which appeared to be the maximum of effect for the red glass. It is impossible to attribute this effect to some feeble quantity of rays, properly called photogenic, passing through the coloured glasses, for we have seen that the blue and violet rays cannot operate under the destructive action of the red rays; this fact proves then evidently, that if the red radiation has a photogenic effect, it cannot be due to the same principle which produces the photogenic effect of the rays situated at the other extremity of the spectrum. The yellow glass has also a peculiar photogenic action of its own, it is a hundred times slower than that of white light, whilst its destructive action is not more than ten times as slow. We can obtain by the photogenic action of the yellow glass an image almost identical, as to force and colour, with an image produced by daylight; with this difference, that the excess of action does not give the blue solarization which we observe upon plates strongly affected by daylight.

The different nature of the photogenic action of red, orange and yellow glasses, from that of the daylight, is also proved by the fact, that the photogenic action produced by these coloured glasses cannot be destroyed by their own reversing action, although the red will destroy the photogenic action of the yellow, and both of these will destroy the action of daylight.

The double property of producing and destroying a photogenic effect is manifested upon a specimen which offers on one-half of the plate a negative image, and upon the other half a positive image, produced at the same time by the same radiation. The length of time necessary to operate with the red glass has not allowed me to obtain a good impression, but I have succeeded perfectly with the yellow glass. The experiment is especially beautiful, and has been thus made:—

I exposed one-half of the plate to daylight for one second, keeping the other half in the dark. The entire plate was then covered with an engraving and exposed under a light yellow glass during ten seconds for the part previously affected by white light, and during a hundred seconds for that which had been kept in the dark. The yellow glass destroyed on the first half the effect of the daylight wherever the plate was not protected by the black lines of the engraving, and the parts only which

under these lines had been protected from the destructive action, received the mercury, producing a negative image; while the same radiation of the yellow glass had operated photogenically upon the other half, developing a positive image by the fixation of mercury upon the parts corresponding to the lights of the engraving.

Having exposed a plate with an engraving under the red glass for sixty minutes, I replaced the red by a yellow glass, without the engraving; after exposing the half of this plate for five minutes under this yellow glass, the other half being kept in the dark, the mercury produced a negative image on the half exposed to yellow light, while the other gave no trace of either positive or negative action. This result can only be explained in the following manner:—

First. That sixty seconds had not sufficed for the apparent action of the red upon the half not exposed to the following radiation of the yellow glass.

Secondly. That nevertheless there had been the commencement of an action upon which the yellow glass had to exercise its destructive action.

Thirdly. That while the yellow glass was occupied in destroying the photogenic action of the red glass, restoring the surface to its primitive state, it was exercising a photogenic action upon the parts protected by the engraving from the red rays, and in five minutes this photogenic action of the yellow glass had produced a negative image by operating upon the shadows of the drawing.

It results from the experiments I have described, that the solar radiation, when modified by coloured media, is in the Daguerreotype process endowed with several different photogenic actions, corresponding with various rays of the spectrum.

The various photogenic actions of the modified solar radiation have distinct characters; each of these modifications is endowed with a photogenic power peculiar to itself, and which gives an affinity for mercurial vapour to the Daguerreotype plate. These various actions are so different, that we cannot mix them artificially to assist each other, as they are antagonistic. The effect commenced by the blue rays is destroyed by the red and yellow; that which was produced by the red is destroyed by the yellow; the effect of the yellow rays is destroyed by the red; and the effect of the two latter is destroyed by the blue; each radiation destroys the effect of the others. Thus it appears that each radiation changes the state of the surface, and each change produces the sensitiveness to mercurial vapour when it does not exist, and destroys this sensitiveness when it does exist.

The alternate change of the state of the plate by these various radiations seems to prove that the chemical compound remains always the same under these different influences; that there is no separation or disengagement of the constituent elements.

If the blue radiation or white light liberates iodine or bromine, these elements would evaporate or combine with the silver surface immediately beneath. If we take the first idea, how comes it that the red radiation re-establishes the compound in its primitive proportions; and, in the second case, how does it happen that these rays are capable of decomposing the surface beneath, liberating the iodine or bromine, and

then combining them again with the upper surface? It is impossible to admit that the red radiation is endowed at the same time with the property of separating and the property of reuniting the same elements. We must then attribute it to a particular force—electricity perhaps, which might accompany each radiation, and which, under the influence of the one, would act positively, and negatively under the other, without changing the chemical compound. In one case this influence would give the affinity for mercury, and in the other destroy it.

At all events, we must look for another explanation of the phenomenon than the one which has hitherto been received, viz. the decomposition of the iodide of silver by the action of light. It is true that light decomposes iodide of silver, forming a subiodide, but this seems to require a longer time than that during which the surface is endowed with the property of attracting the vapours of mercury. In fact, the last property is communicated nearly instantaneously, which is not the case for the decomposition of the iodide by the action of light.